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MRI in Hip Dysplasia: How to Shorten your MR-Protocol?

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Abstract

Objective

Congenital hip dysplasia is a common orthopedic disorder in childhood. MRI is widely used to image high grade dysplastic hips after reduction and fixation within a cast. The purpose of this study was to optimize and shorten the MR study to the requests of the pediatric orthopedic surgeons.

Material and Methods

13 consecutive MR studies of the hip were included in the study (1-5 months of age) between 2003 and 2011. Two pediatric orthopedic surgeons, who were blind for the diagnosis and therapy of the study patients, evaluated all magnetic resonance images (MRI) to determine the type of hip dysplasia. The usefulness of the MR-images was assessed using a 5-point scale. The type of hip dysplasia was assessed using the Tönnis criteria. In addition two radiologists in consensus evaluated the status of sedation and motion artifacts. Original MRI-reports were reviewed.

Results

The most valuable sequences for the position of the femoral head and the evaluation of the anatomic details of the 13 MR-studies were: (a) In coronal planes: TIRM 3 mm (Score 4.6), T2 TSE 3mm (Score 4.1). (b) In axial planes: PD axial 3mm (Score 4.75), DESS reformats 1.5 mm (Score 4.5). (c) All sagittal sequences and non-fat saturated T1w images were not supportive for the orthopedic surgeons. Mild and major motion artifacts are observed in 33% of the patients with sedation and in 71% without sedation.

Conclusion

After reduction of high-grade hip dysplasia and Spica-cast fixation, MRI examination offers valuable information for the orthopedic surgeon. The MRI study may fulfill the orthopedic surgeon's needs using only one coronal and axial plane (e.g. T2w, PD or DESS) to image the dysplastic hip after treatment in a Spica-cast reliably. The shortening of the protocol may reduce the requirement of general anesthesia or sedation, however optimal images without motion artifacts play an important role in image interpretation.

Keywords: MR-imaging; Pediatrics; Congenital; Hip dysplasia; Skeletal-appendicular

Introduction

Congenital hip dysplasia is a common orthopedic disorder in childhood. Untreated dysplastic hips may result in decreased range of motion, leg length discrepancy or luxation and dislocation of the hip and early osteoarthritis [1]. Screening of hip dysplasia provided imaging by ultrasound. The Graf-classification is commonly used and recognized [2]. Severe hip dysplasia is defined as alpha-angles below 43°. Reduction and fixation of the hips in a Spica-cast is the treatment of choice in children with severe hip dysplasia.

Cross sectional imaging (Computed Tomography (CT) or Magnetic Resonance Imaging (MRI)) is the preferred modality in children with dysplastic hips, which were reduced in a closed method and stabilized by a Spica-cast. The primary imaging aim is the reliable and correct interpretation of the femoral head within the socket after closed reduction [3-5]. There are clear advantages of MR-imaging compared to conventional radiographs, CT, and ultrasound. Radiation issues and depiction of the non-ossified femoral epiphysis through a Spica-cast are the primary advantages of MRI.

A variety of sequences are described in the literature for imaging dysplastic hips, which were also in use during daily routine [5-10].

Since no uniform MR-protocol for hip dysplasia in a Spica-cast was used in our institution until the end of 2011, a variety of different sequences were available for comparison.

It was the purpose of the presented retrospective case series to optimize and shorten the MR examination by defining these MR sequences, which are mandatory for pediatric orthopedic surgeons. In particular of interest is the influence of MR-sequences, motion artifacts, and status of sedation on image quality.

Material and Methods

The Institutional Review Board approved this retrospective study. Thirteen consecutive MR studies with a total of 86 MR-sequences were included in this study (1-5 months of age) over a time spam of 2003-2011. All studies were performed on a 1.5T Siemens Erlangen MR unit.

All designated radiology staff members during this time-spam used a protocol based on their expertise. Eight different coronal and axial types of MR-sequences, and 5 sagittal sequences were available

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for comparison.

Motion artifacts were categorized by two radiologists in consensus into no or minor (not or hardly affecting interpretation) and major (greatly affecting interpretation) and compared with the status of sedation (sedation or feed and wrap method).

Two pediatric orthopedic surgeons evaluated 78 MR-sequences for image quality and type of hip dysplasia. Images with major motion artifacts (8 out of 86 sequences) were excluded for the quality assessment of the different MR-sequences. The orthopedic surgeons were blind to patient data and the type of MR-sequence. The MR-images were assessed for their usefulness based on the evaluation of the position of the femoral head within the hip joint on a 1-5 point scale (1= not helpful, 2=insufficient, 3= neutral, 4 = good, 5= excellent). The type of hip dysplasia was evaluated using the Tönnis criteria [11,12]. The pediatric orthopedic surgeons separately determined the management of the patients based on the MR-images.

Results

The average number of sequences per patient was 6.4. All MR-studies were diagnostic, although in some patients, sequences were repeated due to motion artifacts. 6 patients were scanned with general anesthesia, 7 patients were scanned in a "feed and wrap" method. Mild motion artifacts were noted in 33% of the patients in sedation in at least one sequence. Mild or moderate motion artifacts were noted in 71 % of the patients without sedation. In 2 patients moderate motion artifacts in more than one sequence were noted. Eight out of 86 sequences had major motion artifacts (9,3 %), 78 out of 86 (90,7 %) had no or only minor motion artifacts (Figure 1).

The most valuable sequences out of 78 different MR-sequences included for the assessment of the anatomic position of the femoral head were: In coronal planes: TIRM 3mm (Score 4.4, n=5), T2 TSE 3mm (Score 4.1, n=5). In axial planes: PD axial 3mm (Score 4.75, n=2), DESS 1.5mm (Score 4.16, n=3) (Table 1). Only one patient was scanned with intravenous contrast with score of 4.5 in the coronal and score of 4 in the axial plane respectively.

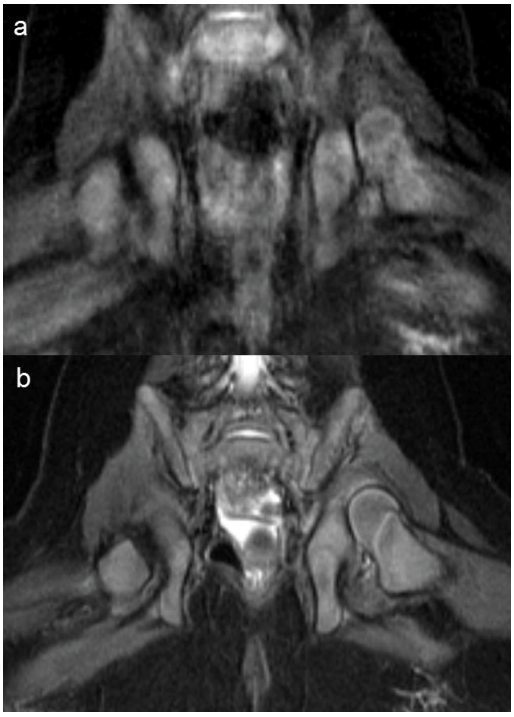

Figure 1: Influence of motion artifacts on image quality in a baby with left hip luxation (a). The coronal TIRM sequence was repeated without motion artifacts (b). There is right dorsal luxation of the femoral head and normal position of the left hip noted.

Nonfat-saturated T1w TSE or FSE, Fl2D, and Fl3D sequences were not considered useful (Score <4). None of the sagittal sequences (Score <2.75) were helpful for the orthopedic surgeons (Table 1).

Management based only on MR-imaging was surgical treatment in 10/13, conservative management in 3/13 patients. Additional arthrography before determining the final management was requested in one patient.

Concerning the Tönnis-criteria, there was good interobserver agreement of the orthopedic surgeons. In 26 hips (left and right hip) examined, 21 (81%) had the same score, five differed by one point. None of the scores differed by more than one point.

Discussion

MRI is useful in the preoperative assessment of complicated DDH and in the evaluation of postsurgical reduction of DDH. MRI provides information about the acetabular labrum, the boundary of the cartilaginous femoral head, may detect bone marrow changes and define the location of the pulvinar.

MRI offers a higher soft tissue contrast compared to CT. The hips are demonstrated in all planes; even 3D imaging and reconstructions are feasible with DESS sequences. The major disadvantages of MR-imaging are the length of the sequences (3-8 minutes) and the number of sequences.

Children with hip dysplasia treated with a Spica-cast after closed or open reduction is often imaged without general anesthesia due to limitations of pediatric anesthesia slots in some institutions. Therefore reliable, fast and robust sequences are needed to image the children with a "feed-and-wrap" method. Motion artifacts are a major concern of this method and many sequences frequently need to be repeated.

Mitchell described the value of MRI undertaken immediately after reduction to minimize the need of sedations [13].

Sequences	Coronar plane		Axial plane		Sagittal plane		Total
	Score	n	Score	n	Score	n	n
TIRM	4.4	5	3.5	2	-	-	7
DESS 3D	3.5	1	4.16	3	2.75	4	8
T2	4.1	5	3.85	11	2	2	18
T2 HASTE	3	1	2.75	2	-	-	3
PDw	3.83	6	4.75	2	2	2	10
T1w	3.86	7	3.625	8	1.5	1	16
T1 FS GD	4.5	1	4	1	-	-	2
Flash2D/ Flash3D	2.17	3	1.86	7	1.5	4	14
Total		29		36		13	78

Abbreviations:
TIRM = *Turbo inversion recovery magnitude* sequence, DESS = Dual echo steady state, HASTE = Half fourier single-shot turbo spin-echo, PDw = Proton density weighted, FS = Fat saturated, GD = Gadolinium, FLASH = Fast Low Angle Shot gradient echo

Table 1: Average image quality of 78 sequences based on the interpretation of two orthopedic surgeons using a 5-point score. N = number of examinations included (images with marked motion artifacts were excluded for this evaluation).

In studies with accurate measurements of the acetabular indices, all patients were sedated, which allows for imaging important details and enhance contrast between cartilage and ossified bone [14]. In these patients anatomic measurements were feasible.

In patients with a Spica-cast, ultrasound is not widely used to characterize the position of the femoral head after reduction. A close collaboration between surgeons and radiologists is necessary in order to optimize the perineal opening to place a US-transducer through a cast [15].

Conventional Radiography (CR) is only appropriate in children at four months of age or older for the diagnosis of developmental dysplastic hips (DDH) from the time when the femoral epiphysis is ossified and radiographically visualized. CR is useful in children for follow-up of treated DDH.

The Tönnis criteria describe the displacement of the femoral head on CR on an AP view [12]. Superolateral displacement of the femur in relation to the acetabulum is a characteristic finding. The interrupted Ménard Shenton's line (line drawn along the inferior border of the superior pubic ramus and along the inferomedial border of the neck of femur) and the axis of the femoral neck which points laterally to the triradiate cartilage may indicate DDH. Since the femoral epiphysis is not yet ossified in children below 4 months of age, femoral displacement is radiographically difficult to depict. In addition, anterior or posterior dislocation of the femoral head may be missed on AP radiographs. Coronal and axial images are valuable to evaluate either dorso-ventral luxation or cranial luxation of the hip. Sagittal planes or reconstructions were considered impractical for the orthopedic surgeons. CT is a very fast and robust method. The availability is high and no sedation is generally needed with the new scanner generation. Reconstructions in all planes are feasible. The limited tissue contrast between cartilage of not ossified femoral epiphysis and soft tissues and the radiation burden are a major weakness of CT in infants.

Different MR-sequences are used to image treated hips within a cast:

T1w TSE images are useful to characterize bone marrow changes in children and to evaluate femoral growth plates with early arrest. T1w FS images are used for MR-arthrography. Aoki et al. detected on T1w images in children older than one year of age important information and obstacles such as hypertrophied pulvinar or inverted limbus [6].

Although many radiologists ordered in our study T1w nonfat-saturated images, they were considered not useful for the orthopedic surgeons, since the bone marrow encompasses red bone marrow and shows hypointense signal intensity. The hypointense signal of cartilage, the ossification center of the epiphysis, and the acetabulum allows no differentiation of the anatomic details (Figure 2).

Fast sequences such as Fl2D or Fl3D sequences were insufficient for the orthopedic surgeons in interpretation of hip dysplasia in young infants due to limited contrast and spatial resolution.

Duffy et al. [14] used coronal and axial fat-saturated fast gradient-echo images. In their study children were scanned with anesthesia. They found that magnetic resonance imaging provides a meaningful way of examining the morphology of the hip joint to determine the likely shape of the ossified acetabulum. It may be possible to use the initial appearance of the cartilaginous anlage of the acetabulum to assess whether a child is likely to require further surgery.

We found optimal imaging characteristics for the hips with DESS-sequence (Double echo steady state). DESS-sequences are a 3D-gradientecho technique with two different gradient echoes. This technique provides optimal contrast of the hip joints, cartilage, bone and joint effusion. Multiplanar reconstructions are feasible. The disadvantage of the DESS-sequence is a long acquisition-time making it more susceptible to motion artifacts (Figure 3).

Conroy et al. [9] found that STIR (Short TI Inversion Recovery) or TIRM (Turbo-Inversion Recovery-Magnitude) imaging in axial planes provided adequate information regarding the position of the femoral head relative to the acetabulum. The sequences are completed within 5 minutes. TIRM offers excellent definition of the cartilaginous acetabulum and femoral head an allows assessment of their relationship to one another [9]. In our study TIRM images were found to be useful mainly in coronal planes. However in our study axial PD sequences or 3D DESS sequences scored better than axial TIRM images, which were more susceptible for motion artifacts (Figure 4).

In 1997 McNally et al. [4] reported on the use of T2* gradient echo sequences for imaging operative reduction of DDH. The high signal of the cartilage delineates the ossific nucleus of the femur. The position of the femoral head is well shown on T2* images. In later publications of

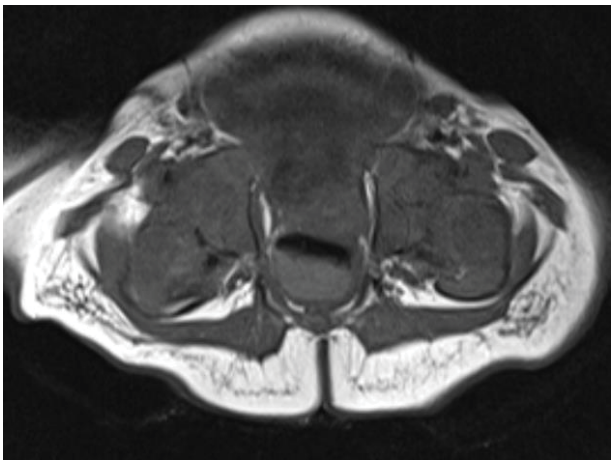

Figure 2: Axial T1w TSE image with insufficient contrast discrimination of hypointense contrast between cartilage, ossified red bone marrow and joint effusion and difficult localizing of the femoral head.

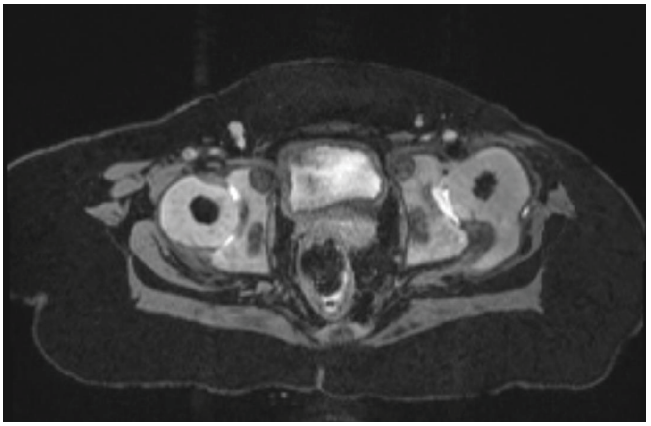

Figure 3: Axial DESS sequence. Optimal perception of cartilage, ossified bone and joint effusion is noted.

hip dysplasia no T2* images were still in use.

T2 FSE sequences in an axial and coronal plane were compared in 3T and 1.5T. Whereas 3T showed significant better image quality in T2W FSE sequences in coronal planes and in older children than 9 months of age. No significant difference was noted in axial planes and between T2 FSE and T1 FSPGR sequences [8].

Gould et al. [10] compared also different sequences for hips after Spica cast placement and found axial and coronal T2 FSE sequences most useful.

In our series T2w TSE images were found to be useful especially in coronal planes (Figure 5). T2w HASTE (ultrafast spin echo sequences) sequences however were considered not to be sufficient for the orthopedic surgeons in all planes.

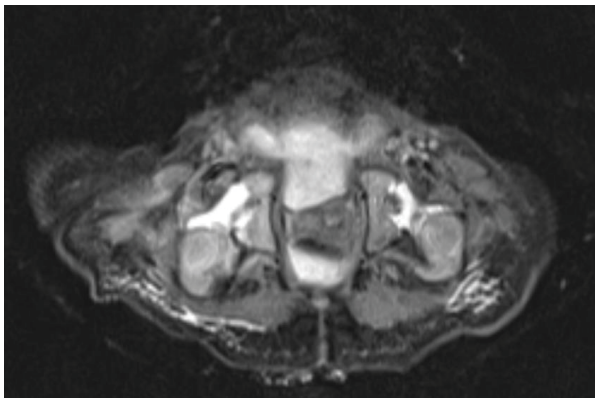

Figure 4: Axial TIRM image. Bilateral dorsal luxation of the hips is noted. There is only moderate contrast between cartilage and ossified bone and mild motion artifacts are noted.

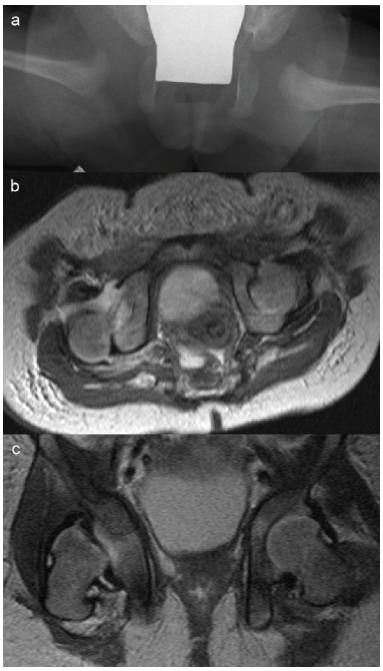

Figure 5: Comparison of CR and T2w MRI (a) the femoral neck points bilaterally towards the triradiate cartilage, which indicates a good position of the femoral head bilaterally. There are round and steep acetabular indices noted. However the consecutive axial (b) and coronal (c) T2w MR-image show right dorsal hip luxation.

Figure 6: Axial PDw MRI of the hip with retroversion and subluxation of the left femoral head. There are clear anatomic details of the hips noted.

Laor et al. [5] recommended coronar T1w images and axial proton density weighted (PDw) fat saturated images as a limited magnetic resonance imaging examination in DDH. PDw images provide excellent spatial resolution, but especially the triradiate cartilage, the contrast is often isointense to the adjacent ossified bone. In our study axial PDw images received the highest scores (4.75), although only 2 exams with PDw images were available in an axial plane (Figure 6).

Limitations of this study are the retrospective nature and the small number of some sequences, which only allows descriptive statistics. There was no evaluation of voxel-size, field of view, and slice thickness in this study. Matrix, field of view and slice thickness play a major role for optimal image quality and image interpretation.

Strength of the study is the interpretation of all sequences by orthopedic surgeons, which highlights the orthopedic needs of MR-interpretation in DDH. A variety of sequences were available for evaluation.

Conclusion

In conclusion, in higher grade dysplastic hips and in fixation in a Spica-cast MRI is reliable and feasible imaging modality. It offers additional information compared to conventional radiographs (Figure 5). The MRI study may be shortened to two sequences; axial and coronal planes (e.g. coronal T2wTSE or TIRM and axial DESS or PDw image) are optimal to image the dysplastic hip after treatment in a Spica-cast.

Motion artifacts remain a major concern and even very fast MR-sequences (Haste, Fl2D) may not entirely eliminate this problem.

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